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Magnetic Properties of Igneous Rocks from Banyuwangi, East Java And Their Reliability for Paleomagnetic Study

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Abstract

We have measured 78 oriented specimens taken form two igneous intrusions in Gunung Nangkajajar at the eastern tip of Java near the town of Banyuwangi for rock magnetic and paleomagnetic investigations. The two intrusions are then referred to as ANBW and DINJ respectively. Upon magnetic measurements, ANBW specimens are found to be magnetically stronger than their DINJ counterparts are. Nevertheless, the specimens in the two sites are suitable for paleomagnetic study as they are magnetically quite isotropic with percent anisotropy well below 10% and magnetic remanence that are stable and consistent upon demagnetization. The consistency of remanence is indicated by the low value of limit or size of cone of confidence, simply referred to as α_{95} and by the high value of precision parameter k. The results show that paleolatitude of these intrusions was about thirty degree South (30°S), which is far south than their present position. The actual motion of these sites is still being investigated, as no absolute age is known for them. Nevertheless, these paleomagnetic finding is very important as no paleomagnetic data ever existed for the eastern tip of Java.

Keywords: *Paleomagnetism, rock magnetism, igneous rocks, tectonic reconstruction of Java*

1. Introduction

Paleomagnetism is a study that deals with measurement of magnetic records in rocks and its implication in tectonic reconstruction, magnetostratigraphy, and the behavior of the Earth's magnetic field. Magnetic recording in rocks, often referred to as magnetic remanence, is possible due to the presence of minute grains of magnetic minerals. The mineralogy and granulometry (grain size distribution) of these grains affect the quality of the recording. Therefore, analysis of mineralogy and granulometry is very important in any paleomagnetic study.

In the year 2002, a model for tectonic reconstruction of the Southeast Asia was published[1], in which, Java is decribed to be rotated in a counter clockwise (CCW) fashion during the Miocene (10-20 million years ago). The modeler, in his personal communication, describes that this 30º CCW rotation of Java was induced from the rotation of the nearby Sumatera and Borneo and was not based on actual paleomagnetic data, which is normally used for such reconstruction. Therefore, paleomagnetic study on Miocene and the older rocks from Java is really required to confirm any prediction of the past movement of Java.

Igneous rocks are suitable candidates for paleomagnetic study in Java as they are distributed continually from the western tip of the island to its eastern tip. Some of the igneous rocks are found to be suitable for dating using K-Ar method and the published ages of some of them are Miocene and older[2,3]. Earlier study using rocks from Central Java shows that intrusive rocks are suitable for paleomagnetic study as they maintain stable magnetic remanence[4].

In this paper, we are reporting the magnetic properties of igneous intrusion from Banyuwangi. It is the preliminary result for paleomagnetic study of the eastern part of Java. To confirm the possible rotation of Java, this study in East Java is essential as the eastern tip of Java should experience higher extent of motion compared to other parts of the island. This study is a part of a long going effort to tectonically reconstruct Java based on paleomagnetic data.

This study is intended as a maiden attempt to use igneous rock from the easternmost part of Java. For this reason, special attention was given to test the reliability of magnetic remanence in the igneous rocks intrusion.

2. Methods

Paleomagnetism is based on the premise that tiny magnetic minerals inside the rocks may faithfully record the direction of the ambient Earth's magnetic field during the rock formation. As the magma cools, minerals are formed and differentiated. As the temperature falls pass through Curie point, some minerals become magnetic and record the Earth's magnetic field direction. In geological time scale this record or magnetic remance is preserved although it might be superimposed by a secondary remanence. In essence, paleomagnetic study is an effort to recover the orientation of the Earth's magnetic field preserved in the remanence of the rocks.

Four oriented hand samples were collected from two locations of igneous intrusions in Gunung (mount) Nangkajajar Banyuwangi, East Java[5] (see Figure 1). The samples were taken from two locations. Samples ANBW1 and ANBW2 were located in 08°24′44.0″ S and 113°59′25.7″ E, while samples DINJ1 and DINJ2 were from 08°24′4605″ S and 113°59′12.7″ E. The dip and azimuth of each intrusion was noted and later used for correcting the direction of remanence (tilt correction).

In total, thirty cylindrical cores with 2.54 cm in diameter were drilled using a specially designed hand drill from the samples. The length of the cores varies from 4 to 20 cm. The cores were then sliced into specimens of 2.2 cm in length. Tops of the cores are avoided, as they were often weathered and therefore not suitable for paleomagnetic study. In all, 78 specimens were obtained.

Paleomagnetic analysis was carried out by, first, measuring the natural remanent magnetization (NRM) of each sample using a Minispin magnetometer (Molspin Ltd., Newcastle upon Tyne, UK). The samples were then subjected to a stepwise alternating field demagnetization using a Molspin AF demagnetizer (Molspin Ltd., Newcastle upon Tyne, United Kingdom) with a peak field of 100 mT. After each step of 2,5 mT, the remanence was measured again using the Minispin. The process was repeated until the measured remanence was 10% of its original NRM or less. Stable direction of remanence in form of its declination and inclination was obtained by the principal component analysis using an algorithm described elsewhere[6)]. The consistency of the remanence direction (declination and inclination) was given by the precision parameter (k) and degree of confidence (α_{95}) parameters.

The samples were also subjected to AMS (anisotropy of magnetic susceptibility) measurement using a Bartington MS2 susceptibility meter with an MS2B sensor (Bartington Instruments Ltd., Oxford, United Kingdom). The instrument uses a low magnetic field of 80 A/m and a frequency of 465 Hz. The AMS was measured by measuring susceptibility in eight different directions [7)] and was then treated as a second-rank tensor represented by the magnitudes along the maximum, intermediate, and minimum susceptibility principal axes (χ_{max}, χ_{int}, and χ_{min}). The average susceptibility, χ_{avg}, is defined as ($\chi_{max} + \chi_{int} + \chi_{min}$)/3 while the anisotropy degree (P) is defined as (χ_{max} /χ_{min}). Other anisotropy parameter, the percent of anisotropy degree (%P) defined as 100% × (P– 1), is also used in this study. The shape parameter, T, is then defined as ($\ln F - \ln L$)/($\ln F + \ln L$), where F (foliation) is (χ_{int} /χ_{min}) and L (lineation) is (χ_{max}/χ_{int})[8)]. Negative T values indicate that the ellipsoid is prolate or rods like in shape, whereas positive values of T indicate oblate or disk like ellipsoids.

To identify the predominant magnetic minerals in the samples, four samples were given IRM (isothermal remanent magnetization) by exposing them to high magnetic field using an electromagnet. The field was given in sequence of increasing magnitude and the remanence after each exposure was measured using the Minispin.

3. Result and Discussion

Table 1 listed the results of AMS measurement and calculation of anisotropy parameters. The result of AMS analysis shows that the specimens, apart from several specimens from ANBW, are fairly isotropic for acquisition of remanent magnetism so that their magnetic remanence likely to be accurate and reliable.

The susceptibility of ANBW specimens varies from 8.366 to 1.937 (× 10^{-6} SI unit). Meanwhile, the susceptibility of DINJ specimens varies from 1.42 to 0.707 (× 10^{-6} SI unit). In general, the DINJ susceptibility values are 10% lower than that of ANBW indicating that magnetic mineral content of ANBW sample is slightly higher than that of DINJ samples. Table 1 also shows that the anisotropy degree of ANBW samples is higher than DINJ samples.

Figure 2 shows the plot of anisotropy degree (P) versus shape factor (T). Positive values of T are dominant indicate that they have oblate-shape more than prolate shape of anisotropy ellipsoids. Another visualization of prolateness or oblateness of susceptibility ellipsoidal can be interpreted from the plot of lineation versus foliation function in Figure 3. It shows that more specimens are located in the oblate side, although some of them are in prolate side.

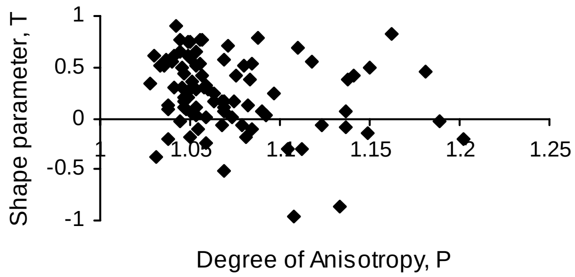


Figure 2. Shape factor (T) as anisotropy degree (P) function for all specimens

Meanwhile, Figure 4 shows the results of IRM acquisition as a function of increasing magnetic field. As IRM for the four representative specimens saturates at a relatively low field (about 100 mT), the predominant magnetic mineral in the samples is very likely to be magnetite or Fe_3O_4[9)].

Table 2 shows average NRM intensity for each sample while Table 3 shows the details of results from NRM measurements and its subsequent demagnetization. In general, the NRM intensity of ANBW specimens is higher than NRM average intensity of specimens from DINJ. The difference of NRM intensity between DINJ and ANBW implies that the magnetic mineral content is higher at ANBW. This in turn suggests that the ANBW may have different magma source and history than the DINJ.

Demagnetization carried out in this study is intended to remove the secondary NRM and to isolate the characteristic NRM (ChRM). Results of progressive alternating field (AF) demagnetization are displayed using an NRM decay curve as well as projection of orthogonal vector component or Zijderveld diagram[9)]. Example of these is given for specimen ANBW113 in Figure 5. It shows that that in general the NRM decayed slowly retaining their stable intensity.

To calculate a mean direction of ChRM and the statistic indicating its scatter, a Fisher statistic is applied. The quality of scatter is characterized by a precision parameter, *k* and the critical angle or limit of confidence, α_{95} [9)]. In paleomagnetism, accuracy of any given direction or position is indicated by the above two parameters as data are distributed following Fisher distribution rather than normal or Gaussian distribution. A computer software called PMGSC was used to calculate the ChRM, *k*, and α_{95} for each specimens. The result of NRM measurement can be seen in Table 3. The stable direction all of specimen was shown by the low value of α_{95}, which vary from 1.1° to 7.9°, and by the high value of *k*, which vary from 39 to 922. All of the specimens are then reliable for paleomagnetic study indicated by low cone of confidence, $\alpha_{95} < 10^{o}$ and precision parameter $k > 25$ [6,9)].

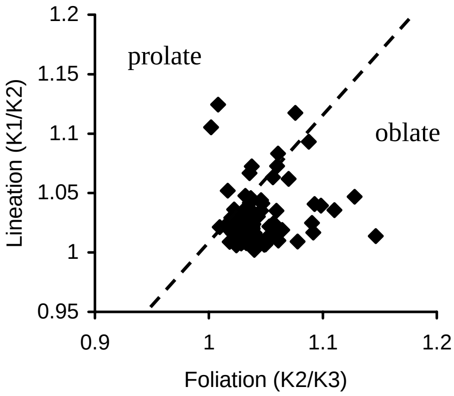


Figure 3. Plot of lineation (*L*) vs foliation (*F*) for all specimens, dashed line is the normal line separating prolate and oblate sides (*F* = *L*).

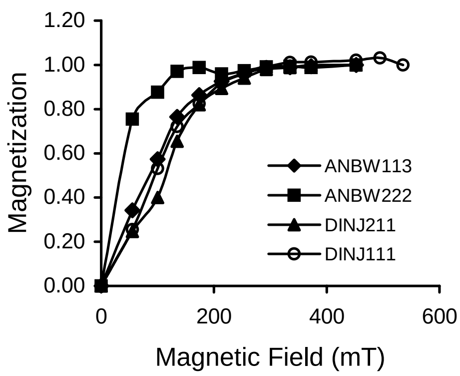
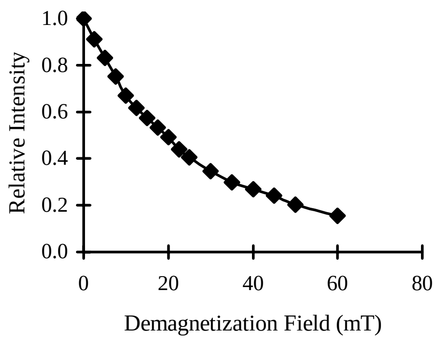
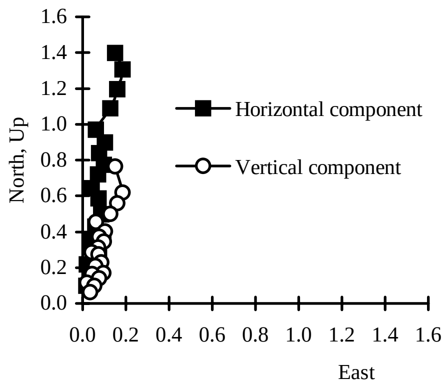


Figure 4. IRM acquisition curves for four representative specimens

Table 4 summarizes the NRM measurement and its implication to the tectonic of Java. It shows the tilt corrected direction of the Earth's magnetic field during the formation of these rocks. The paleolatitudes of these sites were about $33\,^{o}.28^{'}$ – $41\,^{o}\,93^{'}$ south (lower latitude) to $27^{o}13^{'}$ - $30^{o}88^{'}$ south (upper latitude), which is significantly differ from the present latitude. If the samples were indeed Oligo-Miocene in age then the eastern part of Java has moved in a northerly fashion.



(a)



(b)

Figure 5. NRM intensity decay curve (a) and Zijderveld plot of progressive AF demagnetization (b) for typical specimen #ANBW113. Scale of orthogonal plot in mA/m

Compared to the paleolatitude of the Oligo-Miocene andesitic rocks of West Progo, the paleolatitude of Banyuwangi's sites are approximately 15^{o} more southerly than that of sites of West Progo[4)]. This has two possible consequences. First, if the sites of Banyuwangi and that of West Progo were indeed from similar micro continent then that continent must have had rotated in about 15^{o} in a counter clockwise (CCW) fashion in support of the Hall's model of SE Asia tectonic reconstruction[1)]. Second, if the sites of Banyuwangi were not Oligo-Miocene in age it would then should had a quite different origin than the West Progo and tectonic history of Eastern Java would be more complicated than previously thought[10)]. Much better tectonic interpretation will be obtained if the absolute ages of the Banyuwangi sites are known. Regardless of this limitation, paleomagnetic results of these sites should be explored further as they might initiate a better and more comprehensive understanding on the tectonism and tectonic history of Java.

Table 2. The average of NRM intensity

Site ID	Sample ID	NRM Ave.(mA/m)
ANBW	ANBW1	854.6
	ANBW2	989.1
DINJ	DINJ1	203.7
	DINJ2	230.2

4. Conclusion

The igneous rocks from Gunung Nangkajajar in Banyuwangi are magnetically fairly isotropic with relatively low degree of anisotropy. The suitability of these rocks for paleomagnetism is further enhanced by the stability of their magnetic remanence as well as consistency of their inclination and declination during demagnetization process. IRM analysis on representative samples shows that the predominant magnetic mineral is magnetite. The ANBW samples are magnetically stronger than the DINJ sites possible due to its magnetic mineral content. Paleolatitudes calculated from the characteristic NRM suggest that the sites were located around 27^o to 40^o South, which indicates that these sites had moved in a northerly fashion during their geological history. The absence of absolute age limits the extent of tectonic interpretation of these sites. Nevertheless, it is important, as no paleomagnetic data ever existed for the eastern part of Java.

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References

1. Hall, R., *Reconstructing Cenozoic SE Asia*, Journal of Asian Earth Sciences, **20**, p. 353, (2002).
2. Soeria-Atmadja, R., Maury, R.C., Bellon, H., Pringgoprawiro, H., Polve, M., (1994), Tertiary Magnetic Belt in Java, *J. of Southeast Asian Earth Sciences*, 9, 12, 13-27 (1994).
3. Ngkoimani, L., Bijaksana, S., Utoyo, H., Permanadewi, S., New K-Ar Ages of Igneous Rocks from Yogyakarta, Abstract of Workshop on Paleogene Stratigraphy of Java, 2004.
4. Ngkoimani, L., S. Bijaksana, and The Houw Liong, *The Suitability of Andesitic Rocks from Yogyakarta for Paleomagnetic Study*, Proceedings of the 29th Annual Scientific Meeting of HAGI, Yogyakarta, p. 426, 2004.
5. Sapei, T., A. H. Suganda, K. A. S. Astadiredja, and Suharsono, G*eological Map of the Jember Quadrangle, Jawa*, Geological Research and Development Centre, Bandung, 1992.
6. Tauxe, L., *Paleomagnetic principles and practice*, Kluwer Academic Publisher, 1998.
7. Ngkoimani, L., Bijaksana, S., Budiman, A., Sandra, *Measurement of Magentic Susceptibility and Grain Size Determination in Andesitic Rocks* Proceedings of Annual Physics Seminar, Bandung, October, 2003.
8. Jelinek, V., *Characterization of the magnetic fabrics of rocks*, Tectonophysics, **79**, p. T63, (1981).
9. Butler, R. F., *Paleomagnetism Magnetic Domains to Geologic Terranes*, Blackwell Scientific Publishing, 1992.
10. Sribudiyani, N. Muchsin, R. Ryacudu, T. Kunto, P. Astono, I. Prasetya, B. Sapiie, S. Asikin, A. H. Harsolumakso, and I. Yulianto, *The Collision of the East Java Microplate and its Implication for Hydrocarbon Occurrences in the East Java Basin*, Proceeding of the 29th IPA Annual Convention and Exhibition, Jakarta, p, G-085, (2003).

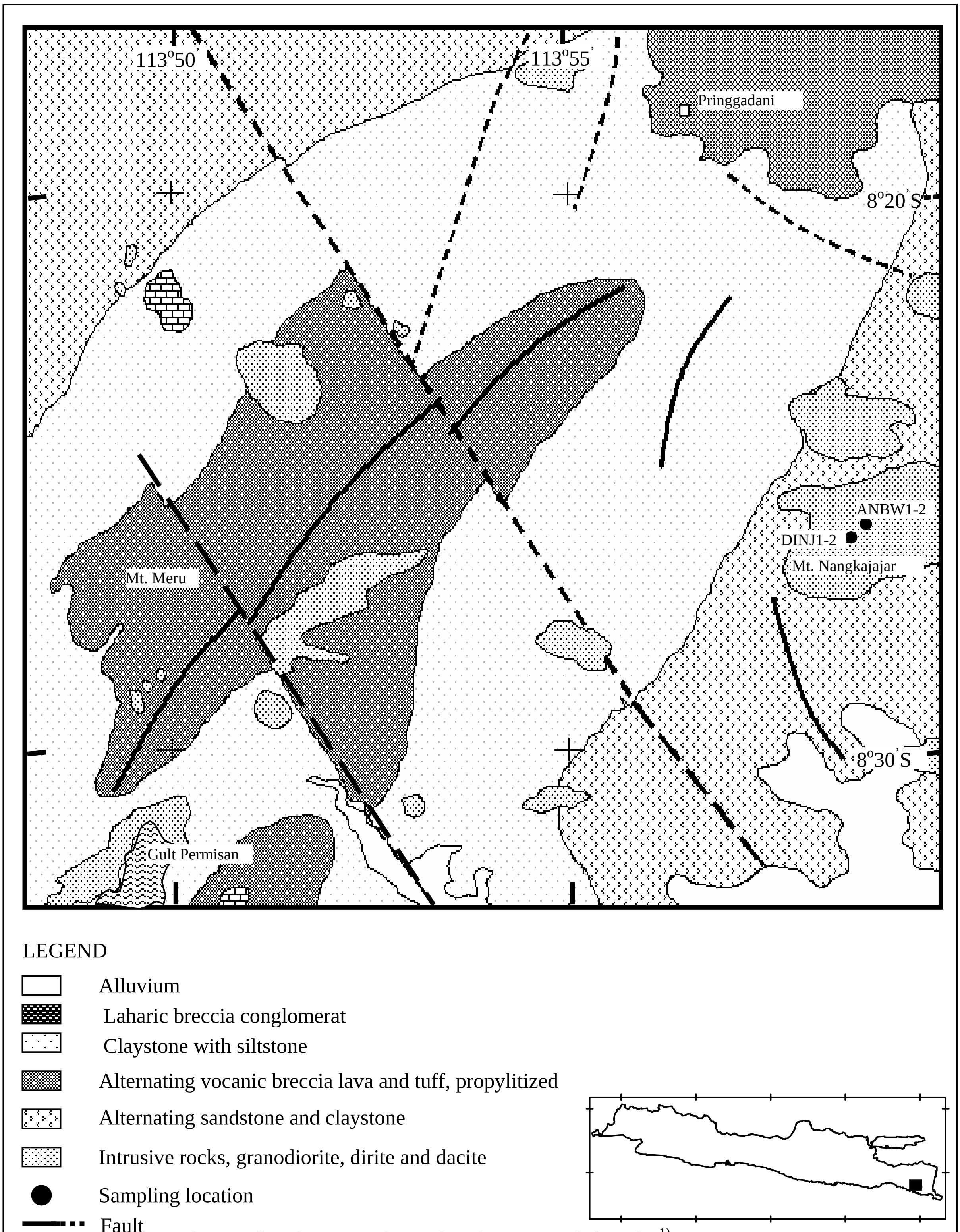

Figure 1. Geological map of study area and sampling location (solid circle)[1).]

Table 1. Summary of AMS measurement

Sample ID	Specimen ID	P	% P	L	F	Km (x10^{-3}SI)	T
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ANBW1	ANBW111	1.137	13.7	1.041	1.093	8.237	0.380
	ANBW112	1.069	6.9	1.052	1.017	7.541	-0.510
	ANBW113	1.117	11.7	1.025	1.090	5.183	0.557
	ANBW121	1.142	14.2	1.039	1.098	5.903	0.417
	ANBW122	1.113	11.3	1.072	1.038	5.597	-0.309
	ANBW123	1.150	15.0	1.035	1.110	2.760	0.500
	ANBW131	1.068	6.8	1.036	1.031	3.667	-0.067
	ANBW132	1.189	18.9	1.093	1.088	2.370	-0.030
	ANBW141	1.105	10.5	1.067	1.036	4.700	-0.297
	ANBW142	1.136	13.6	1.062	1.070	5.803	0.059
	ANBW151	1.181	18.1	1.047	1.128	2.503	0.448
	ANBW152	1.202	20.2	1.117	1.076	5.627	-0.206
	ANBW161	1.046	4.6	1.011	1.034	6.990	0.492
	ANBW171	1.137	13.7	1.073	1.060	4.977	-0.093
	ANBW172	1.053	5.3	1.009	1.044	3.283	0.655
	ANBW173	1.149	14.9	1.083	1.061	1.937	-0.151
	ANBW211	1.036	3.6	1.008	1.028	3.943	0.577
	ANBW212	1.134	13.4	1.124	1.008	2.587	-0.871
	ANBW221	1.082	8.2	1.035	1.045	7.873	0.123
	ANBW222	1.084	8.4	1.046	1.037	8.366	-0.107
	ANBW223	1.074	7.4	1.030	1.043	7.263	0.171
	ANBW231	1.088	8.8	1.009	1.078	4.668	0.785
	ANBW232	1.076	7.6	1.022	1.053	7.270	0.412
	ANBW241	1.162	16.2	1.014	1.146	5.580	0.818
	ANBW242	1.110	11.0	1.017	1.092	7.567	0.681
	ANBW251	1.064	6.4	1.024	1.039	7.147	0.242
DINJ1	DINJ111	1.096	9.6	1.035	1.059	1.420	0.252
	DINJ112	1.027	2.7	1.009	1.018	1.117	0.339
	DINJ113	1.051	5.1	1.024	1.027	0.750	0.043
	DINJ114	1.084	8.4	1.019	1.064	1.045	0.539
	DINJ121	1.051	5.1	1.016	1.035	0.791	0.355
	DINJ122	1.068	6.8	1.028	1.039	1.067	0.159
	DINJ131	1.046	4.6	1.019	1.027	0.766	0.168
	DINJ132	1.047	4.7	1.013	1.034	0.991	0.440
	DINJ133	1.068	6.8	1.016	1.051	1.227	0.512
	DINJ141	1.069	6.9	1.014	1.053	1.363	0.567
	DINJ142	1.049	4.9	1.009	1.039	1.050	0.608
	DINJ143	1.059	5.9	1.029	1.029	0.707	0.016
DINJ2	DINJ211	1.059	5.9	1.036	1.022	0.810	-0.236
	DINJ212	1.057	5.7	1.007	1.050	0.809	0.759
	DINJ213	1.081	8.1	1.048	1.032	0.832	-0.193
	DINJ214	1.055	5.5	1.030	1.024	1.012	-0.101
	DINJ221	1.036	3.6	1.009	1.027	1.143	0.507
	DINJ222	1.038	3.8	1.016	1.021	0.840	0.135
	DINJ223	1.037	3.7	1.022	1.015	0.840	-0.212
	DINJ224	1.041	4.1	1.014	1.026	0.851	0.299

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	DINJ225	1.092	9.2	1.044	1.046	1.140	0.022
	DINJ231	1.058	5.8	1.020	1.038	1.014	0.310
	DINJ232	1.044	4.4	1.022	1.021	0.858	-0.029
	DINJ233	1.042	4.2	1.002	1.040	0.923	0.895
	DINJ234	1.034	3.4	1.008	1.025	0.888	0.512
	DINJ241	1.083	8.3	1.035	1.046	1.137	0.131
	DINJ242	1.050	5.0	1.010	1.039	0.991	0.589
	DINJ243	1.053	5.3	1.019	1.034	0.817	0.288
	DINJ244	1.107	10.7	1.105	1.002	0.866	-0.963
	DINJ251	1.049	4.9	1.019	1.029	1.057	0.211
	DINJ261	1.031	3.1	1.021	1.010	0.968	-0.376
	DINJ262	1.047	4.7	1.018	1.028	1.097	0.211
	DINJ263	1.123	12.3	1.063	1.056	0.934	-0.059
	DINJ271	1.090	9.0	1.041	1.047	0.860	0.062
	DINJ281	1.071	7.1	1.010	1.061	0.994	0.714
	DINJ291	1.050	5.0	1.029	1.020	1.033	-0.188
	DINJ2101	1.083	8.3	1.025	1.057	0.886	0.388
	DINJ2111	1.050	5.0	1.018	1.032	0.899	0.284
	DINJ2112	1.046	4.6	1.016	1.029	0.858	0.292
	DINJ2113	1.069	6.9	1.028	1.039	1.057	0.159
	DINJ2121	1.115	11.5	1.058	1.054	1.373	-0.039
	DINJ2122	1.079	7.9	1.042	1.036	1.443	-0.072
	DINJ2123	1.054	5.4	1.026	1.027	0.961	0.026
	DINJ2124	1.044	4.4	1.008	1.036	0.844	0.643
	DINJ2131	1.041	4.1	1.008	1.033	1.250	0.606
	DINJ2132	1.055	5.5	1.006	1.049	1.051	0.764
	DINJ2133	1.054	5.4	1.024	1.029	0.894	0.099
	DINJ2134	1.055	5.5	1.013	1.042	0.901	0.536

Table 3. Summary of NRM measurements

SAMPLE ID	SPECIMEN ID	NRM Intensity (mA/m)	NRM Characteristic (ChRM)				
			D (°)	I (°)	α_{95} (°)	k	N
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ANBW1	ANBW111	1013.4	3.2	-25.9	1.2	862.3	17
	ANBW112	113.5	5.0	-30.7	2.5	209.9	17
	ANBW113	1599.8	8.3	-24.7	1.5	473.7	20
	ANBW121	1268.9	7.6	-26.9	2.4	214.7	17
	ANBW122	1230.6	1.1	-29.0	1.7	376.4	19
	ANBW123	985.5	358.0	-24.9	1.5	473.8	19
	ANBW131	651.5	3.4	-29.3	2.1	288.4	17
	ANBW132	854.1	1.6	-27.3	1.4	615.6	18
	ANBW141	828.5	6.3	-25.5	2.3	238.9	17
	ANBW142	710.3	3.4	-26.1	2.8	190.1	15
	ANBW143	1936.2	11.9	-23.9	3.1	170.1	14
	ANBW151	702.9	17.1	-29.6	1.1	922.1	18
	ANBW152	1088.7	14.6	-27.1	1.7	386.5	20
	ANBW161	810.0	161.4	-30.8	4.5	61.1	18
	ANBW171	384.4	352.7	-23.3	4.3	60.5	19
	ANBW172	171.1	5.5	-33.7	4.4	235.4	6
	ANBW173	179.2	8.1	-41.8	5.1	41.5	20
ANBW2	ANBW211	1506.3	28.8	-23.8	1.5	231.6	17
	ANBW212	634.3	30.6	-29.2	2.1	258.0	19
	ANBW221	1338.8	0.1	-22.4	2.1	313.4	16
	ANBW222	1068.0	0.4	-17.1	2.0	352.7	16
	ANBW223	899.6	360.0	-16.0	3.4	111.2	17
	ANBW231	819.1	170.0	-23.6	1.5	532.6	18
	ANBW232	883.1	171.1	-20.7	1.8	425.6	16
	ANBW241	497.3	20.3	-23.7	2.0	307.3	17
	ANBW242	686.4	24.1	-20.4	3.9	98.4	15
	ANBW251	1557.6	1.5	-24.0	1.7	450.1	16
DINJ1	DINJ111	337.4	1.0	-74.5	2.4	177.0	21
	DINJ112	267.8	352.6	-76.7	3.3	91.8	21
	DINJ113	182.9	342.4	-71.7	2.7	138.0	21
	DINJ114	132.7	332.4	-70.0	3.5	130.7	14
	DINJ121	168.4	322.7	-69.2	2.9	139.4	19
	DINJ122	101.7	290.6	-68.5	3.8	111.6	14
	DINJ131	132.5	0.9	-77.5	4.3	55.9	21
	DINJ132	209.5	344.9	-77.6	2.2	211.8	21
	DINJ133	238.8	332.3	-75.5	2.1	236.9	21
	DINJ141	306.8	0.9	-72.4	3.0	114.0	21
	DINJ142	235.5	358.4	-72.8	2.6	151.7	21
	DINJ143	130.9	22.9	-79.4	4.2	57.2	21
DINJ2	DINJ211	236.3	153.9	-70.4	2.3	236.9	18
	DINJ212	231.2	311.5	-71.7	2.1	263.0	19
	DINJ213	208.3	299.8	-67.9	2.3	281.5	16
	DINJ214	196.1	299.7	-70.6	5.2	38.7	20
	DINJ221	234.2	0.1	-22.4	2.1	313.4	20
	DINJ222	264.9	328.6	-70.4	1.6	385.5	21
	DINJ223	198.3	310.2	-74.7	3.4	109.9	17
	DINJ224	215.2	305.1	-73.0	5.4	36.2	21
	DINJ225	193.3	309.8	-67.6	3.2	96.9	21

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	DINJ231	242.1	317.9	-69.9	1.6	376.8	21
	DINJ232	210.6	319.9	-71.4	2.4	177.4	21
	DINJ233	247.8	299.6	-73.4	2.8	142.6	19
	DINJ234	192.6	321.9	-80.4	4.9	47.6	19
	DINJ241	275.5	305.5	-68.4	2.0	256.3	21
	DINJ242	213.8	320.2	-71.5	2.2	215.8	20
	DINJ243	196.7	302.4	-73.1	1.5	479.6	21
	DINJ244	195.0	285.5	-71.0	2.3	235.1	17
	DINJ251	277.6	322.6	-69.1	2.1	220.9	21
	DINJ261	258.6	318.6	-67.9	3.1	127.0	18
	DINJ262	267.3	319.7	-71.0	1.1	880.6	21
	DINJ263	195.6	324.9	-72.0	3.8	78.2	19
	DINJ271	214.8	312.9	-69.1	2.5	163.6	21
	DINJ281	204.9	315.4	-71.5	3.3	110.9	18
	DINJ291	222.0	290.5	-67.7	4.4	74.8	15
	DINJ2101	226.9	319.4	-65.9	3.0	113.6	21
	DINJ2111	190.7	301.8	-67.5	5.3	44.3	18
	DINJ2112	247.2	300.7	-68.0	3.3	91.9	21
	DINJ2113	213.4	299.1	-70.7	2.2	212.4	21
	DINJ2121	327.1	308.5	-70.1	1.7	355.3	21
	DINJ2122	235.2	309.4	-73.0	3.1	107.4	21
	DINJ2123	227.8	319.4	-71.4	2.6	150.7	21
	DINJ2124	205.5	295.6	-74.2	3.2	112.0	19
	DINJ2131	276.1	318.4	-70.7	2.4	182.8	21
	DINJ2132	308.1	323.2	-70.6	2.1	154.3	21
	DINJ2133	239.8	307.4	-70.0	2.3	196.4	21
	DINJ2134	195.0	301.4	-68.1	3.8	71.4	21

Table 4. Summary of paleomagnetic data of Mt. Nangkajajar, Banyuwangi

Sample ID	In situ		Dyke correction	Tilt corrected		α_{95} (°)	k	N	Paleo Latitude (°)	Upper latitude (°)	Lower latitude (°)
	Dec (°)	Inc (°)		Dec (°)	Inc (°)						
ANBW1	5.2	-28.3	48/25	300.0	-55.1	2.9	147	18	-35.6	-32.81	-38.61
ANBW2	10.7	-22.3	48/25	312.1	-59.5	9.9	38.1	7	-35.0	-26.25	-46.22
Mean	5.1	-25.8	(48/25)	304.1	-55.0	4.1	70.9	18	-37.4	-33.28	-41.93
DINJ1	339.9	-74.4	65/31	336.8	-43.3	4.1	127.5	12	-25.2	-22.19	-28.53
DINJ2	311.1	-72.2	65/31	325.4	-42.2	2.3	108.9	35	-30.3	-28.28	-32.34
Mean	317.2	-73.0	(65/31)	328.0	-42.6	2.2	93.5	46	-29.0	-27.13	30.88